5. MAJOR ACTIVITIES

In the previous section, we provided a snapshot of the activities we pursue in the Laboratory for Atmospheres. Let's have a closer look. This section presents a more complete picture of our work in measurements, data sets, data analysis, and modeling. In addition, we'll discuss the Laboratory's support for the National Oceanic Atmospheric Administration's (NOAA) remote sensing requirements. Section 5 concludes with a listing of our project scientists, a description of our interactions with other scientific groups, and an overview of our efforts toward commercialization and technology transfer.

Measurements

Studies of the atmospheres of our solar system's planets–including our own–require a comprehensive set of observations, relying on instruments on spacecraft, aircraft, balloons, and on the ground. All instrument systems perform one or both of these functions:

- Provide information leading to a basic understanding of the relationship between atmospheric systems and processes.
- Serve as calibration references for satellite instrument validation, or perform both functions.

Many of the Laboratory's activities involve developing concepts and designs for instrument systems for spaceflight missions, and for balloon-, aircraft-, and ground-based observations. Balloon and airborne platforms let us view such atmospheric processes as precipitation and cloud systems from a high-altitude vantage point but still within the atmosphere. Such platforms serve as a step in the development of spaceborne instruments.

Table II shows the principal instruments that have been built in the Laboratory or for which a Laboratory scientist has had responsibility as Instrument Scientist. The instruments are grouped according to the scientific discipline each supports. Table II also indicates each instrument's deployment—in space, on aircraft or balloons, or on the ground. Further information on each instrument appears on the pages following Table II.

Table II: Principal Instruments Supporting Scientific Disciplines in the Laboratory for Atmospheres

	Atmospheric Structure and Dynamics	Atmospheric Chemistry	Clouds and Radiation	Planetary Atmospheres/Solar Influences
Space		Total Ozone Mapping Spectrometer (TOMS) - Earth Probe (EP) Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE) – Shuttle Earth Polychromatic Imaging Camera (EPIC) - Triana	COmpact Vis IR (COVIR) - Shuttle	Gas Chromatograph Mass Spectrometer (GCMS) – Cassini Huygens Probe Ion and Neutral Mass Spectrometer (INMS) – Cassini Orbiter Neutral Mass Spectrometer (NMS) – *Nozomi* Neutral Gas and Ion Mass Spectrometer (NGIMS) – Comet Nucleus Tour (CONTOUR)
Aircraft	ER-2 Doppler Radar (EDOP) Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)	Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTEL) Raman Airborne Spectroscopic Lidar (RASL)	Cloud Physics Lidar (CPL) Leonardo Airborne Simulator (LAS) Cloud Radar System (CRS)	
Ground/ Laboratory	Scanning Raman Lidar (SRL) Goddard Lidar Observatory for Winds (GLOW) Lightweight Rainfall Radiometer (LRR)	Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE) Tropospheric Ozone Lidar Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA) Aerosol and Temperature Lidar (AT Lidar) Brewer UV Spectrometer Goetz Radiometer SSBUV – Sky Radiance Aerosol Lidar (AL)	Micro Pulse Lidar (MPL) cloud THickness from Offbeam Returns (THOR) Lidar Scanning Microwave Radiometer (SMiR) Surface Measurements for Atmospheric Radiative Transfer (SMART) Sun-Sky-Surface photometer (3S)	

Spacecraft-Based Instruments

The ***Total Ozone Mapping Spectrometer (TOMS***) on Earth Probe (EP) continues to provide daily mapping and long-term trend determination of total ozone, surface ultraviolet (UV) radiation, volcanic SO_2, and UV-absorbing aerosols since 1996. For further information, contact Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

The ***Shuttle Ozone Limb Sounding Experiment/Limb Ozone Retrieval Experiment (SOLSE/LORE)*** measures ozone profiles from the stratosphere down to the tropopause with high vertical resolution. SOLSE is a grating spectrometer that operates in the UV and visible wavelengths while LORE is a filter radiometer with channels in the UV and visible wavelengths. The instruments have been reconfigured in the Laboratory for Atmospheres' Radiometric Calibration and Development Facility to more accurately simulate the performance expected from the Ozone Mapper and Profiler System (OMPS) where both will measure high vertical resolution profiles in the stratosphere down to the tropopause. The OMPS is the ozone sounder instrument planned for the National Polar Orbiting Environmental Satellite System (NPOESS). A SOLSE/LORE reflight is manifested on STS 107 now scheduled for launch in 2002. The mission is partially funded by the Integrated Program Office as a risk mitigation activity for future ozone measurements. For information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov), or Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

Earth Polychromatic Imaging Camera (EPIC) on Triana is a 10-channel spectroradiometer spanning the UV to the near-infrared (IR) wavelength range (317.5 to 905 nm). The main quantities measured are (1) column ozone, (2) aerosols (dust, smoke, volcanic ash, and sulfate pollution), (3) sulfur dioxide, (4) precipitable water, (5) cloud height, (6) cloud reflectivity, (7) cloud phase (ice or water), and (8) UV radiation at the Earth's surface. We will also measure other quantities related to vegetation, bi-directional reflectivity (hotspot analysis) and ocean color. EPIC has two unique characteristics: (1) EPIC takes the first spaceborne measurements from sunrise to sunset of the entire sunlit Earth and (2) EPIC performs the first simultaneous measurements in both the UV and visible wavelengths. These capabilities will allow us to determine diurnal variations and permit extended measurements of aerosol characteristics (2002). The Triana spacecraft and instruments are complete and tested for flight; however, they are temporarily in storage awaiting a flight opportunity. For further information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

COmpact Vis IR (COVIR) is an engineering model of an imaging radiometer for small satellite missions. The instrument is being developed under the Instrument Incubator Program (IIP) and will measure visible and IR wavelengths in the following ranges: 10.3-11.3 µm, 11.5-12.5 µm, 9.5-10.5 µm, and 0.67-0.68 µm. The system employs uncooled microbolometer focal plane detectors. The goal of COVIR is to enable future multisensor Earth-science missions to utilize smaller and lower-cost infrared and visible imaging radiometers. This will lead to improved cloud sensing through increased spatial resolution and coverage with spectral IR data. The design of COVIR is complete. Analysis was completed and a paper submitted on the results of infrared stereo cloud height retrieval by data acquired during the Infrared Spectral Imaging Radiometer shuttle hitchhiker experiment. For further information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The ***Gas Chromatograph Mass Spectrometer (GCMS)*** for the Cassini Huygens Probe will measure the chemical composition of gases and aerosols in the atmosphere of Titan (1997), starting in 2004. For further information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***Ion and Neutral Mass Spectrometer (INMS)*** on Cassini Orbiter will determine the chemical composition of positive and negative ions and neutral species in the inner magnetosphere of Saturn and in the vicinity of its icy satellites (1997), starting in 2004. For further information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***Neutral Mass Spectrometer (NMS)*** on the Japanese spacecraft *Nozomi* (Planet-B) will measure the composition of the neutral atmosphere of Mars to improve our knowledge and understanding of the energetics, dynamics, and evolution of the Martian atmosphere. The Nozomi spacecraft and mission were developed by the Japanese Institute of Space and Astronautical Science (1998). For further information, contact Hasso Niemann (Hasso.B.Niemann.1@gsfc.nasa.gov).

The ***Neutral Gas and Ion Mass Spectrometer (NGIMS)*** on the Comet Nucleus Tour (CONTOUR) mission has been calibrated and delivered to JHU/APL for launch in the summer of 2002. This instrument will provide detailed compositional data on both gas and dust in the near-nucleus environment at precisions comparable to those of Giotto or better (2002). For further information, contact Paul Mahaffy (Paul.R.Mahaffy.1@gsfc.nasa.gov).

Aircraft-Based Instruments

The ***ER-2 Doppler Radar (EDOP)*** is an X-band (9.6 GHz) system which measures vertical profiles of rain and winds within precipitation systems. It has been used for validation of spaceborne rain measurement algorithms used in TRMM and for providing improved understanding of the structure of mesoscale convective systems, hurricanes, and convective storms. It has been involved in 7 major field campaigns with the ER-2, including 3 TRMM validation efforts and 4 CAMEX convection and hurricane campaigns. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov).

The ***Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE)*** measures cloud and aerosol structure and dynamics via laser backscatter in three dimensions. Utilizing a unique conical scanning holographic telescope and a diode pumped solid-state infrared laser, this compact high-performance lidar fits into low- to medium-altitude aircraft as well as in a portable ground-based environmental housing for relatively low-cost field experiment deployments. HARLIE was deployed to Wallops Island for the HARGLO wind intercomparison campaign. The next funded application is in an Army experiment in 2002 as a ground-based sensor to map dust plumes from troop activities at Fort Bliss in El Paso, Texas, to detect aerosol pollution. This will be followed by participation in IHOP during May–June in Oklahoma. Technical descriptions of the instrument and examples of data products are described on the HARLIE Web page: http://harlie.gsfc.nasa.gov/ For further information contact Geary Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

The GSFC ***Airborne Raman Ozone, Temperature, and Aerosol Lidar (AROTEL)*** is a two wavelength lidar system (308 nm and 355 nm) that detects two elastically scattered wavelengths and N_2-Raman scattered radiation at 332 nm and 387 nm. The system uses 20 data channels spread over the four detected wavelengths. The instrument was on board the DC-8 during the SOLVE campaign in the winter of 1999/2000. Colleagues at NASA Langley Research Center contributed data channels for depolarization measurements at 532 nm and channels for aerosol backscatter at 1064 nm. Data products are aerosol backscatter and vertical profiles of ozone and temperature. We plan to install the AROTEL instrument on the DC-8 in another science and validation mission similar to SOLVE, which is scheduled to take place in the winter of 2002/2003, and will involve validation of SAGE III and other satellites. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Raman Airborne Spectroscopic Lidar (RASL)*** was developed under NASA's Instrument Incubator Program (IIP) in collaboration with the Laboratory for Terrestrial Physics. The instrument will address a large number of high-priority atmospheric science measurement requirements, including water vapor, aerosol scattering, extinction, optical depth, depolarization, temperature, cloud liquid water amount and drop size, and cloud top and bottom heights. Through the use of a broadband spectrometer, full spectral tuning across the entire Raman band will also be possible, allowing us to attempt other experimental measurements such as cloud droplet temperature. For information contact David N. Whiteman (David.N.Whiteman.1@gsfc.nasa.gov).

The ***Cloud Physics Lidar (CPL)*** measures cloud and aerosol structure from the high-altitude ER-2 aircraft, in combination with multispectral visible, microwave, and infrared imaging radiometers. The instrument operates at 1064, 532, and 355 nm wavelengths with a repetition rate of 5 kHz. The data are used in radiation and remote-sensing studies. For further information, contact Matthew McGill (Matthew.J.McGill.1@gsfc.nasa.gov).

The ***Leonardo Airborne Simulator (LAS)*** is an imaging spectrometer (hyperspectral) with moderate spectral resolutions. LAS will measure reflected solar radiation to retrieve atmospheric properties such as column water vapor amount, aerosol loadings, cloud properties, and surface characteristics. This was successfully deployed in the SAFARI-2000 campaign in the vicinity of South Africa. The instrument will participate in the July 2002 CRYSTAL/FACE campaign in Florida. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Cloud Radar System (CRS)*** is a W-band (94 GHz) millimeter-wave Doppler radar system for measuring cirrus clouds and other precipitation regions with lower reflectivities (smaller particles) than detectable with conventional rain radars. The system is designed for high-altitude ER-2 operation and operates at the same frequency as the CLOUDSAT radar. The first planned flights are during the CRYSTAL/FACE field campaign during July 2002. For further information, contact Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov).

Ground-Based and Laboratory Instruments

The ***Scanning Raman Lidar (SRL)*** measures light scattered by water vapor, nitrogen, oxygen, and aerosols to determine the water vapor mixing ratio, aerosol backscattering, and aerosol extinction, as well as their structure in the troposphere. Measurements from this mobile system are important for studying radiative transfer, convection, and the hydrological cycle. They are also useful for assessing the water and aerosol measurement capabilities of surface-, aircraft-, and satellite-based instruments.

Using the SRL, a new technique was devised for measuring cloud liquid water, mean droplet radius and droplet number density. A new extension to the theory was developed that allows multiple scattering to be quantified. The technique is based on simultaneously measuring Raman and Mie scattering from cloud liquid droplets using the Raman lidar. The intensity of Raman scattering is known to be proportional to the amount of liquid present in cloud droplets. This fact is used as a constraint on calculated Mie intensity to calculate droplet radius and number density. The general relationship of retrieved average radius and number density is consistent with traditional cloud physics models.

A new technique for measuring cloud base altitude using SRL data was also developed. The technique has advantages over conventional elastic backscatter lidar measurements of cloud base during precipitating periods. A combination of the Raman-lidar-derived profiles of water vapor-mixing ratio and aerosol-scattering ratio, together with the Raman-scattered signals from liquid drops, can minimize or even eliminate some of the problems associated with cloud-boundary detection using elastic lidars. For further information, contact David N. Whiteman (David.N.Whiteman.1@gsfc.nasa.gov)

The ***Goddard Lidar Observatory for Winds (GLOW)*** is a van-based mobile Doppler lidar system that measures vertical profiles of wind from the surface to the stratosphere using the direct-detection Doppler technique. The instrument operates at two wavelengths to measure winds using the laser energy backscattered from aerosols (wavelength=1064 nm) or molecules (wavelength=355 nm). The 1064 nm-channel data products are high spatial-resolution wind profiles in the planetary boundary layer (altitudes < 2km) and the 355 nm channel provides wind profiles in the free troposphere and stratosphere (altitudes as high as 35 km). For further information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The small ***Lightweight Rainfall Radiometer (LRR)*** is a laboratory development under the Instrument Incubator Proposal (IIP) Program. The radiometer will employ an advanced technology Synthetically Thinned Aperture Radiometer (STAR) antenna at 10.7 GHz for future measurements in space. The instrument will provide global high temporal-resolution precipitation measurements from a constellation of small satellites. For further information, contact Eric Smith (Eric.A.Smith.1@gsfc.nasa.gov).

The ***Stratospheric Ozone Lidar Trailer Experiment (STROZ LITE)*** measures vertical profiles of ozone, aerosols, and temperature. The system collects elastically and Raman-scattered returns using DIfferential Absorption Lidar (DIAL). The instrument has participated in over a dozen international measurement campaigns, and is currently deployed to Lauder, New Zealand. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Tropospheric Ozone Lidar*** will measure tropospheric ozone at wavelengths that have a large ozone-absorption cross-section. The system will provide validation data for research and development programs aimed at monitoring tropospheric ozone from space. The system is in development to be completed in early 2002. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Compact Hyperspectral Mapper for Environmental Remote Sensing Applications (CHyMERA)*** instrument is under development in the Atmospheric Chemistry and Dynamics Branch. The primary objective is high-resolution measurement of NO_2, SO_2, aerosol, and O_3. The core design is a wide field-of-view (FOV) front-end telescope that illuminates a filter/focal plane array (FFPA) package. For more information, contact Scott Janz (Scott.J.Janz.1@gsfc.nasa.gov).

The ***Aerosol and Temperature Lidar (AT Lidar)*** is a trailer-based instrument that makes measurements of vertical profiles of atmospheric aerosols and stratospheric temperature. Aerosol information is gathered at three wavelengths to provide particle size information. This instrument is being modified to include water vapor and in-cloud temperature capabilities. For further information, contact Thomas J. McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Brewer UV Spectrometer*** is an operational ground instrument for ozone and UV irradiance measurements. There are many deployed ground-based networks. The Goddard Brewer instrument will have improved calibration and operability for special field campaigns for use as a reference for other network brewer instruments. For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov),

Goetz Radiometer is a ruggedized filter UV radiometer with precision filters and electronics for unattended field use for total and profile ozone and UVB irradiance measurements. The long-term objective is to collect accurate ozone UV and data with low-cost, reliable and highly accurate hardware. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

SSBUV is an SBUV/2 instrument modified for shuttle flight and is now used for zenith sky radiance measurements as part of the Skyrad program. The instrument is a scanning UV spectrometer and has been used as a laboratory standard for prelaunch cross calibration for nearly all BUV-type instruments. For further information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

The ***Aerosol Lidar (AL)*** is a collaborative effort with JPL to build and deploy a small autonomous aerosol lidar for the Network for the Detection of Stratospheric Change. This lidar will transmit 1064 and 532 nm and will retrieve ozone profiles from both those wavelengths. It will also provide depolarization information to determine the physical state of aerosol particles. The first deployment of the lidar will be to a remote site on Christmas Island, near the equator, south of Hawaii. Data will be collected as continuously as possible for a year to gather information on the cloud climatology above the island. If this climatology proves to be satisfactory for atmospheric measurements, further development of the site by the NDSC may proceed. For further information, contact Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The ***Micro Pulse Lidar (MPL)*** makes quantitative measurements of clouds and aerosols. MPL is a unique "eye-safe" lidar system that operates continuously (24 hours a day) in an autonomous fashion. Twenty instruments are currently deployed. In 2000, the MPL program was initiated for continuous lidar monitoring at globally distributed sites. For further information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The cloud ***THickness from Offbeam Returns (THOR)*** Lidar will determine the physical and optical thickness of dense cloud layers from the cloud Green's function, which is the halo of diffuse light up to 0.5 km from the entry point of a lidar beam incident on the cloud layer. Lidar returns at these wide angles are stronger for thicker clouds and are relatively insensitive to cloud microphysics. Cloud thickness is important because clouds provide the single largest internal forcing of the climate system, estimated to be 20 W/m^2 cooling on a global annual average, which is 5 times larger than forcing due to doubled CO_2. This cooling is due to the reflection of solar radiation by clouds, especially the extensive "marine stratocumulus" clouds common over the oceans west of the major landmasses. CLOUDSAT and CALIPSO, due in 2004, together may determine clouds' 3-D structure, for the Earth Observing System (EOS). THOR system provides an inexpensive alternate approach to measuring cloud vertical structure, that eventually can be carried out on unmanned aircraft (UAVs) and perhaps even in space. The reflected "halo" measured by THOR is now being employed in retrieval of cloud properties, using a "nonlocal" approach that improves on the usual "independent pixel approximation" used for standard EOS products. This instrument was funded in 2000 and 2001 under DDF (Directors Discretionary Funds) funding; it is now funded under an RTOP in the Radiation Sciences Program with an expected completion date of 2005. Robert Cahalan is the PI, Matthew McGill the CoI, and John Kolasinski of Code 565 is the Chief Engineer. Planned operations are a validation flight on the Wallops P3 at the Wallops ARM site in the spring of 2002; a co-fly with AMSR on the P3 in the summer of 2002 in the Antarctic night; an ER-2 certification in the fall of 2002; and an ER-2 mission in the spring of 2003. For further information, contact Robert Cahalan (Robert.F.Cahalan.1@gsfc.nasa.gov).

The ***Scanning Microwave Radiometer (SMiR)*** will measure the column amounts of water vapor and cloud liquid water using discrete microwave frequencies. This instrument was successfully deployed in the SAFARI campaign in 2000 and ACE–Asia in 2001. The instrument will be participating in the CRYSTAL/FACE campaign in July 2002. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Surface Measurements for Atmospheric Radiative Transfer (SMART)*** is a suite of surface remote-sensing instruments developed and mobilized to collocate with satellite overpass at targeted areas for retrieving physical/radiative properties of the Earth's atmosphere and for characterizing surface properties. The SMART includes many broadband radiometers, shadow-band radiometers, Sun photometers, solar spectrometers, a whole-sky camera, a micro pulse lidar, and a microwave radiometer, as well as meteorological probes for atmospheric pressure, temperature, humidity, and wind speed/direction. The system will participate in the

CRYSTAL/FACE campaign in July 2002. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

The ***Sun-Sky-Surface photometer (3S)*** is under development in collaboration with Biophysics Branch (Code 923) and Detector System Branch (Code 553). The 3S contains 14 discrete channels, ranging from the ultraviolet to shortwave-infrared spectral region, and scans the upper (atmosphere) and lower (surface) hemispheres during its operation. For further information, contact Si-Chee Tsay (Si-Chee.Tsay.1@gsfc.nasa.gov).

Field Campaigns

Field campaigns typically use the resources of NASA, other agencies, and other countries to carry out scientific experiments or to conduct environmental impact assessments from bases throughout the world. Research aircraft, such as the NASA ER-2 and DC-8, serve as platforms from which remote-sensing and in situ observations are made. Ground systems are also used for soundings, remote sensing, and other radiometric measurements. In 2001, Laboratory personnel supported many such activities as scientific investigators, or as mission participants, in the planning and coordination phases. Field campaigns supported in this way include the following:

An ***Intercomparison of Wind Profile Systems*** involving the HARLIE and GLOW instruments was conducted by scientists from Code 912 at the Atmospheric Physics Measurement Laboratory at NASA Wallops Flight Facility. During the 4-day experiment, wind profile data products from these two lidars were obtained along with wind profile measurements from GPS rawinsondes, NWS rawinsondes, and the SPANDAR Doppler Radar for intercomparison. During the experiment (dubbed HARGLO-2), HARLIE operated nearly continuously while GLOW and SPANDAR provided extended scheduled operations under a variety of atmospheric conditions to produce a large database of wind measurements. For example, GLOW obtained over 27 hours of tropospheric wind profile data during the experiment. Multiple daily rawinsonde launches were also scheduled to supplement the regular twice-daily NWS launches. Both the lidars and SPANDAR operate on the ground looking up, scanning the sky in a conical mode with a 45-degree elevation angle. HARLIE is a 1-micron backscatter lidar utilizing a novel Holographic Optical Element (HOE) scanner, and GLOW is a UV Direct Detection Doppler lidar system. The two took complementary data, HARLIE obtaining its measurements under high aerosol loading and from clouds; and GLOW obtaining its best measurements in clear air using the Rayleigh backscatter from air molecules. SPANDAR obtains its signals from refractive index structure due to moisture and density gradients as well as clouds and aerosols. The rawinsondes derive their wind profiles from the self-tracking of their location during balloon ascent using GPS or Loran geo-location systems. This work was supported by the Integrated Program Office as part of an effort to establish a calibration/validation capability for future spaceborne wind lidar measurements. For further information, contact Mr. G. Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov) or Mr. Bruce Gentry (Bruce.M.Gentry.1@.gsfc.nasa.gov).

Scientists from Code 916 participated in an ***International Dobson Comparison*** organized by NIWA (the New Zealand National Institute of Water and Air Research). Two instruments were sent: a Brewer instrument which measures the total ozone column, and also performs Umkehr measurements to retrieve an ozone profile; and the Stratospheric Ozone Lidar which measures vertical profiles of ozone, aerosol and temperature in the stratosphere. The lidar instrument was able to provide these measurements throughout the night, in order to determine the temporal variability of these parameters. Other participants were NOAA from the U.S., NIWA from New Zealand and CSIRO from Australia. For further information, contact Dr. Thomas McGee (Thomas.J.McGee.1@gsfc.nasa.gov).

The TRMM Satellite Validation Office (TSVO) played a significant role in the ***Keys Area Microphysics Project (KAMP)***, which was part of the NASA's Convection and Moisture Experiment (CAMEX)-4, based in Jacksonville, Florida. KAMP was based in the middle and lower Florida Keys. The TSVO took the opportunity during this program to develop contacts and lay the framework for utilizing the Keys area as a primary Ground Validation (GV) site for TRMM by installing a network of rain gauges and disdrometers to complement radar observations by the permanent WSR-88D radar operated by the Key West Weather Forecast Office, as well as two NASA radars deployed specifically for the experiment. In all, 28 rain gauges were placed and located in several clusters on several different Keys (Big Pine, Big Torch, Cudjoe, Marathon, No Name, Ramrod, Sugarloaf, and Summerland). Four Joss-Waldvogel disdrometers were also deployed, all of which were collocated with rain gauge clusters of two or more gauges. One of the principal goals of the TSVO during KAMP was to show that the radar, gauge and disdrometer data could be quality controlled, processed and distributed in near real-time. This goal was achieved and is documented in the Web site http://trmm-fc.gsfc.nasa.gov/Field_Campaigns/KAMP. For further information, contact Mr. Rich Lawrence (Richard.J.Lawrence.1@gsfc.nasa.gov).

The TOMS group in the Atmospheric Chemistry and Dynamics Branch (Code 916) conducted *a total column ozone intercomparison campaign* in Fairbanks, Alaska, ***TOMS3-F***, to understand the cause of persistent differences between the total column ozone measured by TOMS and ground-based instruments. This location was chosen because these differences appear to be larger under conditions of high ozone, and in Alaska in March ozone is frequently 50% higher than normal— 450 Dobson Units (DU) or more compared to the global average of about 300 DU.

The University of Alaska at Fairbanks hosted the comparison, while Steve Lloyd, Johns Hopkins University, acted as coordinator. Participants included NOAA/CMDL, which brought the World Standard Dobson instrument I83, and the Canadian Atmospheric Environment Service, which brought Brewer Instrument #85, their traveling standard instrument. Information on the vertical profiles of ozone and temperature is critical, so balloon-borne ECC ozonesondes were launched daily by University of Alaska Fairbanks and NOAA/CMDL personnel. Comparisons were also made with ozone profiles from the NOAA 16 SBUV/2 instrument and the NRL POAM instrument.

Initial results show that Brewer total column ozone was on average about 1% higher than TOMS ozone, while Dobson ozone was consistently about 2% lower. Analysis is being done to show how much of the differences between Dobson and TOMS and Brewer can be explained. The Dobson algorithm uses a single climatological temperature, and if the actual temperature deviates significantly, the effective ozone cross section is wrong. High ozone at high latitude is usually associated with very low stratospheric temperatures, which can lead to an underestimate of ozone by Dobson. Both TOMS and Brewer use a latitude- and altitude-dependent temperature climatology. Data from this intercomparison should help resolve the cause of some of the observed differences. For further information, contact Dr. Richard McPeters (Richard.D.McPeters.1@gsfc.nasa.gov).

Scientists from Code 916 played a key role in the ***International Aerosol Characterization Experiments in the Asian Pacific Region (ACE–Asia)***. The campaign is designed to study the compelling variability in spatial and temporal scales of pollution and naturally occurring aerosols over eastern Asia and the western rim of the Pacific. Scientists were responsible for providing model aerosol forecasts to guide daily flight planning. The Georgia Tech/Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model was one of the 3 models used in the field (the other 2 were the NCAR MATCH model and the U. Iowa/U. Kyushi RAMS model).

It has been shown that the constituents forecasting is a very useful tool and played a key role for the field operation, and it will be an indispensable part for the future field missions. The measurements also provide an instantaneous evaluation of the model prediction. The close connection of models and daily field operation benefits both sides. During ACE–Asia, the transport of dust and pollution from the Asian continent was observed on every flight with high concentrations and highly inhomogeneous distributions. The general features were that at low altitudes (below 1 km), most aerosols were pollution aerosols (sulfate and carbonaceous, etc.) which were mixed with dust at higher altitudes, but dust was the major aerosol at altitudes 4 km or above. For further information, contact Mian Chin (Mian.Chin.1@gsfc.nasa.gov).

In April the ***Goddard MP Lidar Network Site*** operated by Code 912 detected an unusual elevated layer of haze considered to be Asian dust that has been transported across the Pacific and North America. It is thought to be the first such observation for the East Coast. Coincidentally the Aerosol Characterization Experiment–Asia (ACE–Asia) was in progress with MP lidars operating in Western China and on the NOAA ship Ron Brown off the coast of Japan. Another MPL site is in Oklahoma. These instruments were intended to track development of the dust layer from its source. Near real-time screen images from the Goddard MPL system can be seen at the following link: http://virl.gsfc.nasa.gov/cgi-bin/Mplnet/nssl.cgi/GSFC/. For further information, contact Dr. James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

Real-time cloud ceiling height information was available to pilots during a rare nighttime landing at the Amundsen-Scott South Pole Research Station to evacuate the station's ailing doctor. A Code 912-operated ***Micro Pulse Lidar (MPL)*** housed at the South Pole since December 1999 provided researchers with extended measurements of optical properties in the lower polar atmosphere. The lidar instruments are highly sensitive to the presence of cloud particles and are inherently effective in giving accurate measurements of cloud base heights. This information could be extremely important to pilots attempting to land at the Pole due to the lack of any sunlight and few distinguishing ground markers near the station. The site meteorologist and communications team in charge of communicating with the pilots will have real-time access to the lidar readings thus allowing them to relay the most up-to-the-moment cloud information to the pilots as they prepare and execute their descent and landing at the Pole. More information: http://virl.gsfc.nasa.gov/mpl-net/. For further information, contact Mr. James Campbell (James.Campbell.1@gsfc.nasa.gov).

The ***TRACE-P*** Science Team designed the flight tracks for the NASA P3B and DC-8 over the first weekend of operations in late February, from the chemical forecasts provided by the Harvard TRACE-P team, using the forecast products from the Goddard DAO. The flights were seeking an Asian CO plume located at 135W, 43N, according to the forecast. Near real-time forecast products were used to predict regions of high and low carbon monoxide and ozone. Flights were then directed to these targets, with the goal of understanding the production and outflow of polluted air off of the Asian continent. The flight team cited numerous times when the ability of the DAO system to represent frontal structures and related convective activity has led to successful missions. The DAO specifically developed numerical schemes to represent meteorological realism, and this served as verification of projected model capabilities. For further information, contact Dr. Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

The ***South Pole Experiment*** site is part of the MPL-Network and an important part of preparations for the GLAS satellite mission. The lidar continuously monitors the structure and properties of clouds. In order to characterize the effect of clouds for the upcoming GLAS mission, the experiment included angular scans through vertical to measure the lidar signal increase at zenith from gravitationally aligned ice crystals. The Micro Pulse Lidar data show the presence and height structure of Polar Stratospheric Clouds (PSCs) for most of the 2001 austral winter. PSCs were initially found at 16 to 20 km altitudes in June. In addition to PSCs, blowing snow clouds extending from the surface to 10 to 200 meters altitude were almost continuously present during the winter. The South Pole Experiment is in collaboration with the University of Washington and is believed to be the first full-time lidar monitoring in Antarctica. Ref. http://virl.gsfc.nasa.gov/mpl-net/. For further information, contact Dr. James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The SSBUV has seen the sky for the first time since 1996 on its last shuttle flight. Under a new Code 916 program, ***Skyrad***, the instrument observed zenith sky radiances in the UV from the RCDF clean room. The objective of this program is to collect data to improve radiative transfer models and algorithms. They are used by TOMS, SBUV, ground-based Dobson and Umkehr sensors and to perform validations for TOMS, SBUV/2, and Envisat SCIAMACHY (to be launched this October). The technique could be applicable to future operational ozone sounders (NPOESS-US, Eumetsat-Europe, and GCOM-Japan). For further information, contact Mr. Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

NASA sponsored the ***Convection and Moisture Experiment 4 (CAMEX-4)*** which focused on hurricane research in the eastern Atlantic region. The campaign was conducted jointly with NOAA and university scientists, and was under the U.S. Weather Research Program (USWRP) hurricane landfalling program. One of the high-priority goals of Goddard scientists in Code 912 and UMBC/JCET and GEST scientists was to measure high-altitude temperature and wind measurements simultaneously with radar measurements of the hurricane. The NASA ER-2 and DC-8 aircraft were instrumented with numerous remote sensing and in situ instruments to provide high resolution, detailed measurements of the structure of hurricanes. Two instruments played a key role in measuring the warm core of a mature hurricane. The Goddard ER-2 Doppler Radar (EDOP) is a downward-looking instrument that measures radar reflectivity and vertical velocity in precipitation regions. The ER-2 High-altitude Dropsonde system (EHAD) was a joint effort between JCET and NCAR. High-altitude dropsondes were released by EHAD into a hurricane while simultaneous radar measurements were taken by EDOP. These data sets are being analyzed to more fully understand the dynamics related to hurricane intensification. For further information, please contact Dr. Gerald Heymsfield (Gerald.M.Heymsfield.1@gsfc.nasa.gov) or Dr. Jeffrey Halverson (Jeffrey.B.Halverson.1@gsfc.nasa.gov).

Data Sets

In the previous discussion, we examined the array of instruments we use to gather weather and climate data. Once we have obtained the raw data from these instruments, we arrange the information into data sets useful for studying various atmospheric phenomena.

TIROS Operational Vertical Sounder Pathfinder

The Pathfinder Projects are joint NOAA/NASA efforts to produce multiyear climate data sets using measurements from instruments on operational satellites. One such satellite-based instrument suite is the TIROS Operational Vertical Sounder (TOVS). TOVS is comprised of three atmospheric sounding instruments: the High Resolution Infrared Sounder-2 (HIRS-2), the Microwave Sounding Unit (MSU), and the Spectral Sensor Unit (SSU). These instruments have flown on the NOAA Operational Polar Orbiting Satellite since 1979. We have reprocessed TOVS data from 1979 to the present, using an algorithm developed in the Laboratory to infer temperature and other surface and atmospheric parameters from TOVS observations.

The TOVS Pathfinder Path A data set covers the period 1979–2001 and consists of global fields of surface skin and atmospheric temperatures, atmospheric water vapor, cloud amount and cloud height, OLR and clear sky OLR, and precipitation estimates. The data set includes data from TIROS N, and NOAA 6,7,8,9,10,11,12, and 14. Equivalent future data sets will be produced from

NOAA 15 and 16 ATOVS data and from AIRS data on EOS Aqua. We have demonstrated that TOVS data can be used to study interannual variability of surface and atmospheric temperatures and humidity, cloudiness, OLR, and precipitation. We have developed the 22-year TOVS Pathfinder Path A data set. The TOVS precipitation data is being incorporated in the monthly and daily GPCP precipitation data sets. We are developing improved methodologies to analyze ATOVS data to produce a future climate data set and also to use in conjunction with the DAO data assimilation system to improve analyses and numerical weather prediction skill. We have also developed the methodology to be used by the AIRS science team to generate products from AIRS for weather and climate studies. In joint work with the DAO, the AIRS sounding products will be assimilated into the DAO GEOS 3 system to demonstrate how well the AIRS data will improve weather prediction skill. For more information, contact Joel Susskind (Joel.Susskind.1@gsfc.nasa.gov).

Tropospheric Ozone Data

Gridded data sets on tropospheric column ozone (TCO) and stratospheric column ozone (SCO) in the tropics for 1979–present are now available from NASA Goddard Space Flight Center via either direct ftp, World Wide Web, or electronic mail. Until recently, the primary method to derive TCO and SCO from satellite data was by combining TOMS and SAGE ozone measurements. At NASA Goddard, monthly averaged TCO and SCO data are derived in the tropics for January 1979–present using the convective cloud differential (CCD) method [Ziemke et al., J. Geophys. Res., 103, 22115-22127, 1998]. Further details regarding methodology and new adjustments made for aerosol contamination are discussed in Ziemke et al. [Bull. Amer. Meteorol. Soc., 81,580-583, 2000; J. Geophys. Res., 9853-9867, 2001]. These data have recently been used in several published studies within Code 916 to characterize tropospheric ozone variabilities from monthly to decadal time scales. The CCD, TCO, and SCO data may be obtained via World Wide Web (http://hyperion.gsfc.nasa.gov/Data_services/Data.html). For more information, contact Jerry Ziemke (Jerald.R.Ziemke.1@gsfc.nasa.gov) or Sushil Chandra (Sushil.Chandra.1@gsfc.nasa.gov).

Aerosol Products from the Total Ozone Mapping Spectrometer

Laboratory scientists are generating a unique new data set of atmospheric aerosols by reanalyzing the 17-year data record of Earth’s ultraviolet albedo as measured by the TOMS. Since 1996, Laboratory staff members have developed techniques for extracting aerosol information from measured UV radiances. The UV technique differs from conventional visible methods in that the UV measurements can reliably separate UV absorbing aerosols (such as desert dust and smoke from biomass burning) from nonabsorbing aerosols (such as sulfates, sea-salt, and ground-level fog). In addition, the UV technique can measure aerosols over land and can detect all types of aerosols over snow/ice and clouds.

TOMS aerosol data are currently available in the form of a contrast index (and now as optical depth). The index provides excellent information about sources, transport, and seasonal variation of a variety of aerosol types. Work is currently in progress to release the data relating the index to aerosol optical thickness and single-scatter albedo.

Recently, new methods have been developed to quantitatively detect aerosols using SeaWiFS visible channels over many types of land surfaces as well as the oceans. Because of the high spatial resolution (1 km) we are now able to investigate the sources of dust and smoke by combining the data with calculations from high-resolution transport models. An example of this type of analysis has been made showing dust flowing through mountain passes in Afghanistan and Iran. The aerosol data is also being used to assess the degree of radiative forcing (excess heating) in the atmosphere caused by the presence of dust. The results are used to estimate heating rates related to climate change. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

Multiyear Global Surface Wind Velocity Data Set

The Special Sensor Microwave Imagers (SSM/I) aboard three Defense Meteorological Satellite Program (DMSP) satellites have provided a large data set of surface wind speeds over the global oceans from July 1987 to the present. These data are characterized by high resolution, coverage, and accuracy, but their application has been limited by the lack of directional information. In an effort to extend the applicability of these data, the DAO developed methodology to assign directions to the SSM/I wind speeds and to produce analyses using these data. This methodology has been used to generate a 14-year data set (from July 1987 through June 2001) of global SSM/I wind vectors. These data are currently being used in a variety of atmospheric and oceanic applications and are available to interested investigators. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Global Precipitation Data Set

An up-to-date, long, continuous record of global precipitation is vital to a wide variety of scientific activities. These include initializing and validating numerical weather prediction and climate models, providing input for hydrological and water cycle studies, supporting agricultural productivity studies, and diagnosing intra-annual and interannual climatic fluctuations on regional and global scales.

At the international level, the Global Energy and Water Cycle Experiment (GEWEX) component of the World Climate Research Programme (WCRP) established the Global Precipitation Climatology Project (GPCP) to develop such global data sets. Scientists working in the Laboratory have led the GPCP effort to merge microwave data from low-Earth-orbit satellites, infrared data from geostationary satellites, and data from ground-based rain gauges to produce the best estimates of global precipitation.

Version 2 of the GPCP merged data set provides global, monthly precipitation estimates for January 1979–present. Updates are being produced on a quarterly basis. The release includes input fields, combination products, and error estimates for the rainfall estimates. The data set is archived at World Data Center A (located at the National Climatic Data Center in Asheville, North Carolina), at the Goddard Distributed Active Archive Center (DAAC), and at the Global Precipitation Climatology Centre (located at the Deutscher Wetterdienst in Offenbach, Germany). Evaluation is ongoing for this long-term data set in the context of climatology, ENSO-related variations and trends, and comparison with the new TRMM observations. Development of data sets with finer time resolution (daily and 3-hr) is proceeding. A daily, global analysis for 1997–present has also been completed for the GPCP and is available from the archives. A 3-hr resolution rainfall analysis combining TRMM and other satellite data is being developed and is currently being tested. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

SHADOZ (Southern Hemisphere ADditional OZonesondes) Data Set

The first-archived data set dedicated to tropical and subtropical ozonesonde profiles is coordinated in Code 916 within the Laboratory. Initiated in 1998 as a unique effort to fill in gaps in the tropical ozone profile record, SHADOZ (Southern Hemisphere ADditional OZonesondes) meets community needs for development of ozone retrieval satellite algorithms, validation of new ozone products, global chemical-transport model evaluation and for basic understanding of ozone in the tropics [Thompson et al., 2002]. With weekly ozonesonde launches at 10 tropical stations, and occasional tropical field campaigns, SHADOZ supplies high-quality ozone and temperature profiles to ~35 km and relative humidity to 12 km. In less than 4 years, over 1300 profiles have been added to the world's ozone data record. Thompson, A.M., et al., The 1998–2000 SHADOZ

(Southern Hemisphere ADditional OZonesondes) Ozone Climatology. 1. Comparison with TOMS and ground-based measurements, J. Geophys. Res., in press, 2002. For more information, contact Anne Thompson (Anne.M.Thompson.1@gsfc.nasa.gov).

Multiyear Data Set of Satellite-Based Global Ocean Surface Turbulent Fluxes

The fluxes of momentum (or wind stress), latent heat (due to evaporation), and sensible heat, called turbulent fluxes, at the global ocean surface are essential to weather, climate, and ocean problems. These fluxes are required for driving ocean models and validating coupled ocean-atmosphere global models, as well as performing climate studies. The Special Sensor Microwave/Imagers (SSM/I) aboard a series of Defense Meteorological Satellite Program (DMSP) satellites have provided near-global coverage with improved coverage, spatial resolution, and accuracy over prior passive microwave instruments. Laboratory scientists have developed methodology to produce a Version 2 data set of Goddard Satellite-Based Surface Turbulent Fluxes (GSSTF-2) from the SSM/I radiances and other data. It provides daily- and monthly-mean turbulent fluxes and some relevant parameters over global oceans for the period July 1987–December 2000 and the 1988–2000 annual- and monthly-mean climatologies of the same variables. These variables are wind stress, latent heat flux, sensible heat flux, 10-m wind speed, 10-m specific humidity, sea-air humidity difference, and lowest 500-m bottom-layer precipitable water. Its spatial resolution is 1° latitude x 1° longitude. The data set is archived at the Goddard Distributed Active Archive Center (DAAC) and participates in the Ocean Surface Turbulent Flux Project (SEAFLUX) for comparison with other flux data sets. For more information, contact Shu-Hsien Chou (Shu-Hsien.Chou.1@gsfc.nasa.gov).

Data Analysis

Atmospheric Ozone Research

The Clean Air Act Amendment of 1977 assigned NASA major responsibility for studying the ozone layer.

Data from many ground-based, aircraft, and satellite missions are combined with meteorological data to understand the factors that influence the production and loss of atmospheric ozone. Analysis is conducted over different temporal and spatial scales, ranging from studies of transient filamentary structures that play a key role in mixing the chemical constituents of the atmosphere to investigations of global-scale features that evolve over decades.

The principal goal of these studies is to understand the complex coupling between natural phenomena, such as volcanic eruptions and atmospheric motions, and human-made pollutants, such as those generated by agricultural and industrial activities. These nonlinear couplings have been shown to be responsible for the development of the well-known Antarctic ozone hole.

An emerging area of research is to understand the transport of chemically active trace gases across the tropopause boundary. It has been suggested that changes in atmospheric circulation caused by greenhouse warming may affect this transport and, thus, delay the anticipated recovery of the ozone layer in response to phase-out of CFCs. For more information, contact Paul A. Newman (Paul.A.Newman.1@gsfc.nasa.gov).

Total Column Ozone and Vertical Profile

Laboratory for Atmospheres scientists have been involved in measuring ozone since the late 1960s when a satellite instrument, the Backscatter Ultraviolet (BUV) Spectrometer, was launched on NASA's Nimbus-4 satellite to measure the column amount and vertical distribution of ozone. These measurements are continuing aboard several follow-on missions launched by NASA, NOAA, and, more recently, by the ESA.

An important activity in the Laboratory is developing a high-quality, long-term ozone record from these satellite sensors and comparing that record with ground-based and other satellite sensors. This effort, already more than a quarter century in duration, has produced ozone data sets that have played a key role in identifying the global loss of ozone due to certain human-made chemicals. This knowledge has contributed to international agreements to phase out these chemicals by the end of this century. For more information, contact Pawan K. Bhartia (Pawan.K.Bhartia.1@gsfc.nasa.gov).

Surface UV Flux

The primary reason for measuring atmospheric ozone is to understand how the UV flux at the surface might be changing and how this change might affect the biosphere. The sensitivity of the surface UV flux to ozone changes is calculated using atmospheric models and the measured values of ozone, aerosol, and cloud amounts. Yet, until recently, we had no rigorous test of these models, particularly in the presence of aerosols and clouds. By comparing a multiyear data set of surface UV flux generated from TOMS data and high-quality ground-based measurements, especially those from a cooperative effort with the U.S. Department of Agriculture, we are increasingly able to quantify the respective roles of ozone, aerosols, and clouds in controlling the surface UV flux over the globe. While the agreement between satellite and ground-based measurements of surface UB flux is becoming good, the satellite data covers regions not normally accessible by the ground-based instruments (e.g., oceans, deserts, etc.). We have recently extended the analysis of UV flux for penetration into the deep oceans and coastal regions. For more information, contact Jay Herman (Jay.R.Herman.1@gsfc.nasa.gov).

Data Assimilation

The DAO in the Laboratory has taken on the challenge of providing to the research community a coherent, global, near real-time picture of the evolving Earth system. The DAO is developing a state-of-the-art Data Assimilation System (DAS) to extract the usable information available from a vast number of observations of the Earth system's many components, including the atmosphere, the oceans, the Earth's land surfaces, the biosphere, and the cryosphere (ice sheets over land or sea).

The DAS is made of several components including an atmospheric prediction model, a variational physical space analysis scheme, and models to diagnose unobservable quantities. Each of these components requires intense research, development, and testing. Much attention must be given to insuring that the components interact properly with one another to produce meaningful, research-quality data sets for the Earth system science research community. (See later section on Modeling). For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov) .

Observing System Simulation Experiments

Since the advent of meteorological satellites in the 1960s, considerable research effort has been directed toward designing space-borne meteorological sensors, developing optimum methods for using satellite soundings and winds, and assessing the influence of satellite data on weather prediction. Observing system simulation experiments (OSSE) have played an important role in this research. Such studies have helped in designing the global observing system, testing different methods of assimilating satellite data, and assessing the potential impact of satellite data on weather forecasting.

At the present time, OSSEs are being conducted to (1) provide a quantitative assessment of the potential impact of currently proposed space-based observing systems on global change research, (2) evaluate new methodology for assimilating specific observing systems, and (3) evaluate tradeoffs in the design and configuration of these observing systems. Specific emphasis over the past year has been on space-based lidar winds and advanced passive sensors. For more information, contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Seasonal-to-Interannual Variability and Prediction

One of the main thrusts in climate research in the Laboratory is to identify natural variability on seasonal, interannual, and interdecadal time scales, and to isolate the natural variability from the human-made global-change signal. Climate diagnostic studies use a combination of remote-sensing data, historical climate data, model outputs, and assimilated data. Climate diagnostic studies will be combined with modeling studies to unravel physical processes underpinning climate variability and predictability. The key areas of research include the El Niño Southern Oscillation (ENSO), monsoon variability, interseasonal oscillation, and water vapor and cloud feedback processes. A full array of standard and advanced analytical techniques, including wavelets transform, multivariate empirical orthogonal functions, singular value decomposition, canonical correlation analysis, and nonlinear system analysis are used.

The Laboratory, in conjunction with the Laboratory for Hydrospheric Processes (Code 970), plays a lead role in NASA's Seasonal-to-Interannual Prediction Project (NSIPP). NSIPP promotes and facilitates collaboration between NASA and outside scientists in developing a coupled ocean-atmosphere-land modeling system to predict El Niño events, and their impacts on the extratropics by utilizing a combination of satellite and in situ data. NSIPP will also employ a high-resolution atmosphere-land data assimilation system that will capitalize on a host of new high-resolution satellite data including MODIS and Landsat. This capability will allow scientists to better characterize the local and remote physical processes that control regional climates and limit predictability.

Promoting the use of satellite data for better interpretation, modeling and eventually prediction of geophysical and hydroclimate system is a top priority of research in the Laboratory. Satellite-derived data sets for key hydroclimate variables such as rainfall, water vapor, clouds, surface wind, sea surface temperature, sea level heights, land surface characteristics from the EOS Terra and Aqua series, from TRMM, QuikSCAT and TOPEX/Poseidon and Jason-1, as well as from the Earth Radiation Budget Experiment (ERBE), the International Satellite Cloud Climatology Project (ISCCP), Advanced Very High Resolution Radiometer (AVHRR), SSM/I, MSU, and TOVS Pathfinder data will be used extensively for diagnostic and modeling studies. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Rain Measurements

Rain Estimation Techniques from Satellites

Rainfall information is a key element in studying the hydrologic cycle. A number of techniques have been developed to extract rainfall information from current and future spaceborne sensor data, including the TRMM satellite and the Advanced Microwave Scanning Radiometer (AMSR) on EOS Aqua.

The retrieval techniques include the following: (1) A physical, multifrequency technique that relates the complete set of microwave brightness temperatures to rainfall rate at the surface. This multifrequency technique also provides information on the vertical structure of hydrometeors and on latent heating through the use of a cloud ensemble model. The approach has recently been extended to combine spaceborne radar data with passive microwave observations. (2) An empirical relationship that relates cloud thickness and other parameters to rain rates, using TOVS sounding retrievals. (3) An analysis technique that uses low-orbit microwave, geosynchronous infrared, and rain gauge information to provide a merged, global precipitation analysis. The merged analysis technique is now being used to produce global daily and tropical 3-hourly analyses.

The satellite-based rainfall information has been used to study the global distribution of atmospheric latent heating, the impact of ENSO on global-scale and regional precipitation patterns, the climatological contribution of tropical cyclone rainfall, and the validation of global models. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

Rain Measurement Validation for the TRMM

The objective of the TRMM Ground Validation Program (GVP) is to provide reliable, instantaneous area- and time-averaged rainfall data from several representative tropical and subtropical sites worldwide for comparison with TRMM satellite measurements. Rainfall measurements are made at Ground Validation (GV) sites equipped with weather radar, rain gauges, and disdrometers. A range of data products derived from measurements obtained at GV sites is available via the Goddard DAAC. With these products, the validity of TRMM measurements will be established with accuracies that meet mission requirements. For more information, contact Robert Adler (Robert.F.Adler.1@gsfc.nasa.gov).

Predicting Errors in Satellite Rainfall Measurements

To use TRMM maps of monthly rainfall, we need some measure of the accuracy of the satellite average. We have developed a statistical model of rain behavior that predicts that the random error in satellite rainfall averages–not including systematic biases that might be present–should depend in a straightforward way on the local average rain amounts and simple measures of rain variability. We have seen behavior consistent with the prediction in a number of studies based on simulations using rain gauges and radar data. The model prediction has recently been confirmed using rain observations from the Defense Meteorological Satellite Program satellites. Based on the model, we are developing a simple method of estimating the error levels in satellite rainfall so that satellite rain products can be accompanied by documented estimates of intrinsic error in the averages provided. For more information, contact Thomas L. Bell (Thomas.L.Bell.1@gsfc.nasa.gov).

Reference:

Bell, T.L., P.K. Kundu, and C.D. Kummerow, 2001: Sampling Errors of SSM/I and TRMM Rainfall Averages: Comparison with Error Estimates from Surface Data and a Simple Model. J. Appl. Meteor., 40, 938-954.

Aerosols/Cloud Climate Interactions

Theoretical and observational studies are being carried out to analyze the optical properties of aerosols and their effectiveness as cloud condensation nuclei. These nuclei produce different drop size distributions in clouds, which, in turn, will affect the radiative balance of the atmosphere.

We developed algorithms to routinely derive aerosol loading, aerosol optical properties, and total precipitable water vapor data products from the EOS-Terra Moderate Resolution Imaging Spectroradiometer (MODIS). These algorithms are being evaluated, modified, and verified using the global MODIS data and information from the Aerosol Robotic Network (AERONET) of sun/sky radiometers. MODIS and AERONET data are being used to evaluate the global distribution of aerosols, their properties, and their radiative forcing of climate. Evaluation of the MODIS aerosol data with AERONET shows that they are as accurate as predicted in papers from 1997 and that MODIS and Landsat data are also used to measure a key aerosol property important to understanding climate change—namely aerosol absorption of sunlight. Measurements of absorption of sunlight by Saharan dust particles show that they absorb only 1/3 as much as the value previously used in models of the last decade. This change in dust's absorption properties suggests it has a much stronger effect on the Earth's energy balance than previously suspected. For more information, contact Yoram Kaufman (Yoram.J.Kaufman.1@gsfc.nasa.gov).

Laboratory scientists are actively involved in analyzing data recently obtained from national and international campaigns. These campaigns include the Puerto Rico Dust Experiment (PRiDE) which observed transported Saharan dust in the Caribbean, the Southern Africa Fire-Atmosphere Research Initiative (SAFARI) 2000 which characterized aerosols from southern African biomass burning, and the Chesapeake Lighthouse Aircraft Measurements for Satellites (CLAMS) which was an excellent opportunity to characterize both aerosol and various ocean surface conditions off the East Coast of the United States. For more information, contact Lorraine Remer (Lorraine.A.Remer.1@gsfc.nasa.gov).

Hydrologic Processes and Radiation Studies

Scientists in the Climate and Radiation Branch of the Laboratory are developing methods to estimate atmospheric water and energy budgets. These methods include calculating the radiative effects of absorption, emission, and scattering by clouds, water vapor, aerosols, CO_2, and other trace gases. Algorithms for global measurements of aerosol thickness are developed from MODIS data. Calibration/validation and scientific experiments on aerosols and clouds are conducted in various climatic regions of the world, with ground-based and airborne instruments, e.g., the SAFARI experiment in South Africa, PRiDE in Puerto Rico, and ACE–Asia in central Asia. Also developed are arrays of highly mobile and versatile measurement platforms for direct measurements of surface radiation, water vapor and cloud properties for deployments in field campaigns, e.g., Surface Measurements for Atmospheric Radiation Transfer (SMART) and the off-beam lidar (THOR) for cloud thickness measurements.

Using long-term satellite and satellite-blended data and four-dimensional assimilated data, Laboratory scientists study the response of radiation budgets to changes in water vapor and clouds during El Niño events in the Pacific basin and during westerly wind-burst episodes in the western tropical Pacific warm pool. Also investigated are the relative importance of large-scale dynamics and local thermodynamics on clouds and radiation budgets and modulating sea surface temperature. In addition, research effort is devoted to understanding and predicting the impacts of basin-scale sea surface temperature fluctuations such as the El Niño on regional climate variability over the Indo-Pacific region, North America, and South America. For more information, contact William Lau (William.K.Lau.1@gsfc.nasa.gov).

Modeling

Coupled Atmosphere-Ocean-Land Models

To study climate variability and sensitivity, we must couple the atmospheric GCM with ocean- and land-surface models. Much of the work in this area is conducted in collaboration with Goddard's Laboratory for Hydrospheric Processes, Code 970. The ocean models predict the global ocean circulation–including the sea surface temperature (SST)–when forced with atmospheric heat fluxes and wind stresses at the sea surface. Land-surface models are detailed representations of the primary hydrological processes, including evaporation; transpiration through plants; infiltration; runoff; accumulation, sublimation, and melt of snow and ice; and groundwater budgets.

One of the main objectives of coupled models is forecasting seasonal-to-interannual anomalies such as the El Niño phenomenon. Laboratory scientists are involved in the NASA Seasonal-to-Interannual Prediction Project (NSIPP), which was established in collaboration with Goddard's Laboratory for Hydrospheric Processes. NSIPP's main goal is to develop a system capable of assimilating hydrologic data and using that data with complex, coupled ocean-atmosphere models to predict tropical SST with lead times of 6–14 months. A second goal is to use the predicted SST in conjunction with coupled atmosphere-land models to predict changes in global weather patterns.

NSIPP is currently producing routine seasonal forecasts. Each month surface and subsurface hydrographic data are assimilated to produce initial conditions for the ocean component of a coupled ocean-atmosphere-land forecast system. A 10-member ensemble forecast is then integrated for 1 year. In addition to this coupled forecast of SST, NSIPP also performs monthly "Tier 2" forecasts, using predicted SSTs to force more detailed atmospheric models. NSIPP's forecasts are available on the Internet at http://nsipp.gsfc.nasa.gov and are used by prediction centers for guidance in their assessments.

In addition to its forecasting work, NSIPP is engaged in research activities in land surface modeling, coupled processes, low-frequency atmospheric phenomena, and various aspects of data assimilation. More on this work can be found at the above Web site, together with a large archive of model-simulated data. For information, contact Max Suarez (Max.J.Suarez.1@gsfc.nasa.gov).

Global Modeling and Data Assimilation

Development of the Data Assimilation System

The DAO currently uses the GEOS-3 DAS to support the EOS Terra Mission. The GEOS-3 DAS is a major upgrade of the GEOS-1 DAS used for the first NASA reanalysis. The GEOS-3 DAS provides data products at a higher horizontal resolution (1° longitude by 1° latitude) and employs a new Physical-space Statistical Analysis System (PSAS). Other improvements include an interactive Mosaic-based land surface model, a state-of-the-art moist turbulence scheme, an on-line estimation and correction procedure for systematic forecast errors, and assimilation of space-borne observations of marine surface winds, total precipitable water, and Level 1B radiances from TOVS using a 1D variational scheme.

For the EOS-Aqua and beyond, the DAO is developing a next-generation numerical model for climate prediction and data assimilation in collaboration with NCAR. In addition, DAO is developing advanced data assimilation techniques using a combination of Kalman filtering and four-dimensional variational approaches. These techniques will allow us to make better use of synoptic observations. DAO is also developing flow-dependent covariance models to maximize the benefit of high spatial resolution of the observations and of the model.

In FY01, the Data Assimilation Office has released the first version of its next generation data assimilation system. This system involves a state-of-the-art general circulation model based on the finite-volume dynamical core developed at DAO, coupled to physical parameterizations from NCAR. The system employs an adaptive statistical quality control, which examines the quality of the input data stream taking in consideration the "flow of the day." The system ingests data from a variety of conventional and remotely sensed data including rawinsondes, TOVS Level 1B radiances and scatterometers. In the core of the assimilation algorithm is DAO's Physical-space Statistical Analysis System (PSAS), a global 3-D VAR class solver that combines model short-term forecast with observations to provide an optimal estimate of the atmospheric state. Compared to the previous GEOS-3.2 operational system, the next generation system has superior forecasts skills, has a much improved stratospheric circulation, realistically captures the evolution of synoptic systems, and has a competitive climate. The Finite-volume Data Assimilation System (fvDAS) is scheduled to become operational in the first half of 2002. For more information contact Robert Atlas (Robert.M.Atlas.1@gsfc.nasa.gov).

Cloud and Mesoscale Modeling

The mesoscale (MM5) and cloud-resolving (Goddard Cumulus Ensemble–GCE) models are used in a wide range of studies, including investigations of the dynamic and thermodynamic processes associated with cyclones and frontal rainbands, tropical and mid-latitude deep convective systems, surface (i.e., ocean and land, and vegetation and soil) effects on atmospheric convection, cloud-chemistry interactions, and stratospheric-tropospheric interaction. Other important applications include assessment of the potential benefits of assimilating satellite-derived water vapor, winds and precipitation fields into tropical and extra-tropical regional-scale (i.e., hurricanes and cyclones) weather simulations, and climate applications. The latter involves long-term integrations of the models that allow for the study of air-sea and cloud-radiation interactions and their role in cloud-radiation-climate feedback mechanisms. Such simulations provide an integrated systemwide assessment of important factors such as surface energy and radiative exchange processes, and diabatic heating and water budgets associated with tropical and mid-latitude weather systems.

Data collected during several major field programs, GATE (1974), PRESTORM (1985), TOGA COARE (1992–1993), SCSMEX (1998), TRMM LBA (1999), TRMM KWAJEX (1999) and CAMEX 3/4 (2000/2001), was used to improve as well as to validate the GCE and MM5 model. The MM5 was also improved in order to study regional climate variation, hurricanes and severe weather events (i.e., flash floods in the central U.S.). The models also are used to develop retrieval algorithms. For example, GCE model simulations are being used to provide TRMM investigators with four-dimensional cloud data sets to develop and improve TRMM rainfall and latent heating retrieval algorithms. Four-dimensional latent heating structures (1° by 1°, monthly) were retrieved from December 1997 to November 2000. For more information, contact Wei-Kuo Tao (WeiKuo.Tao.1@gsfc.nasa.gov).

Physical Parameterization in Atmospheric GCM

The development of physical submodels of the climate system is an integral part of climate modeling activity. Laboratory scientists are actively involved in developing and improving physical parameterizations of the major radiative transfer and moisture processes in the atmosphere. Both of these areas are extremely important for eliminating model biases and leading to a better understanding of the global water and energy cycles.

For atmospheric radiation, we are developing efficient, accurate, and modular longwave and shortwave radiation codes. The radiation codes allow efficient computation of climate sensitivities to water vapor, cloud microphysics, and optical properties. The codes also allow us to compute the global warming potentials of carbon dioxide and various trace gases.

For atmospheric hydrologic processes, we are evaluating and improving a prognostic cloud liquid water scheme, which includes representation of source and sink terms as well as horizontal and vertical advection of cloud material. This scheme incorporates attributes from physically based cloud life cycles, including the effects of downdraft, cloud microphysics within convective towers and anvils, cloud-radiation interactions, and cloud inhomogeneity corrections. We are evaluating coupled radiation and the prognostic water schemes with in situ observations from the ARM and TOGA-COARE IOPs as well as satellite data. For land-surface processes, a new snow physics package is being evaluated with GEWEX GSWP data sets. It is currently in the GEOS GCMs. Moreover, the soil moisture prediction is extended down to 5m, which often goes through the groundwater table. All these improvements are found to better represent the hydrologic cycle in a climate simulation. For more information, contact Yogesh Sud (Yogesh.C.Sud.1@gsfc.nasa.gov).

Trace Gas Modeling

The Atmospheric Chemistry and Dynamics Branch has developed two- and three-dimensional models to understand the behavior of ozone and other atmospheric constituents. We use the two-dimensional models primarily to understand global scale features that evolve in response to both natural effects, such as variations in solar luminosity in ultraviolet, volcanic emissions, or solar proton events, and human effects, such as changes in chlorofluorocarbons (CFCs), nitrogen oxides, and hydrocarbons. The three-dimensional models simulate the evolution of ozone and trace gases that affect ozone. The constituent transport is calculated utilizing meteorological fields (winds and temperatures) generated by the DAO. These calculations are appropriate to simulate variations in ozone and other constituents for time scales ranging from several days or weeks to seasonal, annual, and interannual. The model simulations are compared with observations, with the goal of improving our understanding of the complex chemical and dynamical processes that control the ozone layer.

The modeling effort has evolved in four directions: (1) Lagrangian models are used to calculate the chemical evolution of an air parcel along trajectory. The Lagrangian modeling effort is primarily used to interpret aircraft and satellite chemical observations. (2) Two-dimensional (2-D) noninteractive models have comprehensive chemistry routines, but use specified, parameterized dynamics. They are used in both data analysis and multidecadal chemical assessment studies. (3) Two-dimensional interactive models include interactions among photochemical, radiative, and dynamical processes, and are used to study the dynamical and radiative impact of major chemical changes. (4) Three-dimensional (3-D) models have a complete representation of photochemical processes and use input meteorological fields from either the data assimilation system or from a general circulation model for transport. The constituent fields calculated using winds from a new general circulation model developed jointly by the DAO and the National Center for Atmospheric Research exhibit many observed features. We are exploring coupling this GCM with the stratospheric photochemistry from the CTM with the goal of developing a fully interactive 3-D model that is appropriate for assessment calculations.

The Branch uses trace gas data from sensors on the UARS, on other satellites, from ground-based platforms, from balloons, and from various NASA-sponsored aircraft campaigns to test model processes. The integrated effects of processes such as stratosphere troposphere exchange, not resolved in 2-D and 3-D models, are critical to the reliability of these models. For more information, contact Anne Douglass (Anne.R.Douglass.1@gsfc.nasa.gov).

Support for National Oceanic and Atmospheric Administration Operational Satellites

In the preceding pages, we examined the Laboratory for Atmosphere's work in measurements, data sets, data analysis, and modeling. In addition, Goddard supports NOAA's remote sensing requirements. Laboratory project scientists support the NOAA Polar Orbiting Environmental Satellite (POES) and the Geostationary Operational Environmental Satellite (GOES) Project Offices. Project scientists assure scientific integrity throughout mission definition, design, development, operations, and data analysis phases for each series of NOAA platforms. Laboratory scientists also support the NOAA SBUV/2 ozone measurement program. This program is now operational within the NOAA/National Environmental Satellite Data and Information Service (NESDIS). A series of SBUV/2 instruments flies on POES. Post-doctoral scientists work with the project scientists to support development of new and improved instrumentation and to perform research using NOAA's operational data.

Laboratory members are actively involved in the NPOESS Internal Government Studies (IGS) and support the Integrated Program Office (IPO) Joint Agency Requirements Group (JARG) activities. Likewise, the Laboratory is supporting the formulation phase for the next generation GOES mission, known as GOES-R.

Geostationary Operational Environmental Satellites

NASA GSFC project engineering and scientific personnel support NOAA for the GOES operational satellites. GOES supplies images and soundings to study atmospheric processes, such as moisture, winds, clouds, and surface conditions. In particular, GOES observations are used by climate analysts to monitor the diurnal variability of clouds and rainfall and to track the movement of water vapor in the upper troposphere. In addition to high-quality imagery, the GOES satellites also carry an infrared multichannel radiometer that NOAA uses to make hourly soundings of atmospheric temperature and moisture profiles over the United States. These mesoscale soundings are improving NOAA's numerical forecasts of local weather. The GOES project scientist at Goddard provides free public access to real-time weather images for regions all over the western hemisphere via the World Wide Web (http://rsd.gsfc.nasa.gov/goes/). For more information, contact Dennis Chesters (Dennis.Chesters.1@gsfc.nasa.gov).

Polar-Orbiting Environmental Satellites

Algorithms are being developed and optimized for the HIRS-3 and the Advanced Microwave Sounding Unit (AMSU) first launched on NOAA 15 in 1998. Near real-time analysis will be carried out thereafter, as was done with HIRS2/MSU data. For more information, contact Joel Susskind (Joel.Susskind.1@gsfc.nasa.gov).

Solar Backscatter Ultraviolet/2

NASA has the responsibility to determine and monitor the prelaunch and postlaunch calibration of the SBUV/2 instruments that are included in the payload of the NOAA polar-orbiting satellites. We further have the responsibility to continue the development of new algorithms to determine more accurately the concentration of ozone in the atmosphere.

The NOAA 16 SBUV/2 instrument was launched and has gone through testing. It has now been operational since March 2001. Because the EP TOMS instrument is undergoing a degradation of its scanning mirror, the NOAA 16 SBUV/2 is now our primary measurement for the long-term ozone record. We are in the process of integrating the data from this instrument into our long-term record. This is being accomplished by comparing its data to both EP TOMS and the NOAA 11 SBUV/2 to evaluate their relative calibrations.

We have previously produced a single merged data set with a common calibration that extends from November 1978 through the end of 2000. We have recently updated this record to include the NOAA 16 data through the end of 2001. The data are available on the Web at http://code916.gsfc.nasa.gov/Data_services/merged/. For more information, contact Richard Stolarski (Richard.S.Stolarski.1@gsfc.nasa.gov).

National Polar-Orbiting Environmental Satellite System

The first step in instrument selection for NPOESS was completed with Laboratory personnel participating on the Source Evaluation Board, acting as technical advisors. Laboratory personnel were involved in evaluating proposals for the OMPS (Ozone Mapper and Profiler System) and the Crosstrack Infrared Sounder (CrIS), which will accompany ATMS, an AMSU-like crosstrack microwave sounder. Collaboration with the IPO continues through the Sounder Operation Algorithm Teams (SOAT) and the Ozone Operational Algorithm Team (OOAT), which will provide advice on operational algorithms and technical support on various aspects of the NPOESS instruments. In addition to providing an advisory role, members of the Laboratory are conducting internal studies to test potential technology and techniques for NPOESS instruments. We have conducted numerous trade studies involving CrIS and ATMS, the advanced IR and microwave sounders, which will fly on NPP and NPOESS. Simulation studies were conducted to assess the ability of AIRS to determine atmospheric CO_2, CO, and CH_4. These studies indicate that total CO_2 can be obtained to 2ppm (0.5%) from AIRS under clear conditions, total CH_4 to 1%, and total CO to 15%. This shows that AIRS should be able to produce useful information about atmospheric carbon. For more information, contact Joel Susskind (Joel.Susskind.1@gsfc.nasa.gov).

For OMPS, Laboratory scientists continue to support the IPO through the OOAT. The team conducts algorithm research and provides oversight for the OMPS developer. An algorithm is being developed to analyze SAGE III data when SAGE III operates in a limb scattering mode, which will simulate retrievals expected from the OMPS profiler. This work is an extension of the retrievals used for the SOLSE/LORE shuttle mission conducted in 1997. The SOLSE/LORE payload was developed in the Laboratory for Atmospheres. The retrievals from this shuttle mission demonstrated the feasibility of employing limb scattering to observe ozone profiles with high vertical resolution down to the tropopause. This research is enabled by the advanced UV and visible radiative transfer models developed in the Laboratory. Laboratory scientists also participate in the Instrument Product Teams to review all aspects of the OMPS instrument development. The IPO is supporting a reflight of SOLSE/LORE on the Space Shuttle, in July 2002, as a risk mitigation effort related to the OMPS. For more information, contact Ernest Hilsenrath (Ernest.Hilsenrath.1@gsfc.nasa.gov).

CrIS is a high-spectral-resolution interferometer infrared sounder with capabilities similar to those of the Atmospheric Infrared Sounder (AIRS). AIRS will fly with AMSU A and HSB on the EOS Aqua platform to be launched in 2002. Scientific personnel have been involved in developing the AIRS Science Team algorithm to analyze the AIRS/AMSU/HSB data. These data will be used in a pseudo-operational mode by NOAA/NESDIS and NOAA/NCEP. Simulation studies were conducted for the IPO to compare the expected performance of AIRS/AMSU/HSB with that of CrIS, as a function of instrument noise, together with AMSU/HSB. The simulations will help in assessing the noise requirements for CrIS to meet the NASA sounding requirements for the NPOESS Preparatory Project (NPP) bridge mission in 2005. Trade studies have also been done for the Advanced Technology Sounder (ATMS), which will accompany CrIS on the NPP mission and replace AMSU/HSB. For more information, contact Joel Susskind (Joel.Susskind.1@gsfc.nasa.gov).

Tropospheric wind measurements are the number one priority in the unaccommodated Environmental Data Records (EDR) identified in the NPOESS Integrated Operational Requirements Document (IORD-1). The Laboratory is using these requirements to develop new technologies and Direct Detection Doppler Lidar measurement techniques to measure tropospheric wind profiles on a global scale. The IPO is supporting the effort through their IGS program. For more information, contact Bruce Gentry (Bruce.M.Gentry.1@gsfc.nasa.gov).

The Instrument Incubator Program is supporting the development of a visible and infrared imaging radiometer based on advanced-technology array detectors. The goal is an imaging radiometer smaller, less costly, and more capable than previous instruments. The program is developing an instrument based on advanced microbolometer array (MBA) warm thermal detectors. A prototype MBA-based instrument, the ISIR, flew as a shuttle small-attached payload in August 1997. Its performance proved the capability and advantages for MBA detectors in space applications. The Compact Visible and Infrared Imaging Radiometer (COVIR) is an engineering model of an operational flight instrument and will be completed and tested in 2001. A shuttle flight experiment is planned for early 2003. For more information, contact James Spinhirne (James.D.Spinhirne.1@gsfc.nasa.gov).

The IPO supports the development of Holographic Scanning Lidar Telescope technology as a risk reduction for lidar applications on NPOESS, including, but not limited to, a direct detection (edge) wind lidar system. Currently used in ground-based and airborne lidar systems, holographic scanning telescopes operating in the visible and near infrared wavelength region have reduced the size and weight of scanning receivers by a factor of three. We are currently investigating extending the wavelength region to the ultraviolet, increasing aperture sizes to 1 meter and larger, and eliminating all mechanical moving components by optically addressing multiplexed holograms in order to perform scanning. This last development should reduce the weight of our current large aperture scanning receivers by another factor of three. For more information on the Holographic Optical Telescope and Scanner (HOTS), visit the Web site at http://virl.gsfc.nasa.gov/lazer/index.html or contact G. Schwemmer (Geary.K.Schwemmer.1@gsfc.nasa.gov).

Project Scientists

Spaceflight missions at NASA depend on cooperation between two upper-level managers, the project scientist and the project manager, who are the principal leaders of the project. The project scientist provides continuous scientific guidance to the project manager while simultaneously leading a science team and acting as the interface between the project and the scientific community at large.

Table III: Laboratory for Atmospheres Project, Deputy Project, and Mission and Study Scientists

PROJECT SCIENTISTS		DEPUTY PROJECT SCIENTISTS	
Name	**Project**	**Name**	**Project**
Pawan K. Bhartia	TOMS	Anne R. Douglass	EOS Aura ,UARS
Dennis Chesters	GOES	Ernest Hilsenrath	EOS Aura
Jay Herman	Triana	Arthur Hou	TRMM
		Si-Chee Tsay	EOS Terra
Robert Adler	TRMM	Marshall Shepherd	GPM
Charles Jackman	UARS		
Joel Susskind	POES		
Robert Cahalan	EOS SORCE		
Eric Smith	GPM		
EOS VALIDATION SCIENTIST		**MISSION AND STUDY SCIENTISTS**	
		Name	**Project**
David O'C. Starr	EOS	Matt McGill	Cloud Sat
		Matt McGill	CALIPSO
		Robert Atlas	GTWS

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Interactions with Other Scientific Groups

Interactions with the Academic Community

The Laboratory depends on collaboration with university scientists to achieve its goals. Such relationships make optimum use of government facilities and capabilities and those of academic institutions. These relationships also promote the education of new generations of scientists and engineers. Educational programs include summer programs for faculty and students, fellowships for graduate research, and associateships for postdoctoral studies. A number of Laboratory members teach courses at nearby universities and give lectures and seminars at U.S. and foreign universities. The Laboratory frequently supports workshops on a wide range of scientific topics of interest to the academic community, as shown in Appendix 5.

NASA and non-NASA scientists work together on NASA missions, experiments, and instrument and system development. Similarly, several Laboratory scientists work on programs residing at universities or other federal agencies.

The Laboratory routinely makes its facilities, large data sets, and software available to the outside community. The list of refereed publications, presented in Appendix 7, reflects our many scientific interactions with the outside community.

Prime examples of collaboration between the academic community and the Laboratory include these cooperative agreements with universities (a complete list may be found at the Web site http://webserv.gsfc.nasa.gov/ESD/collab.html):

- Earth System Science Interdisciplinary Center (ESSIC), with the University of Maryland, College Park;

- Joint Center for Earth Systems Technology (JCET), with the University of Maryland, Baltimore County;
- Goddard Earth Sciences and Technology Center (GEST Center), with the University of Maryland, Baltimore County, (and involving Howard University);
- Center for Earth-Atmosphere Studies (CEAS), with Colorado State University;
- Cooperative Center for Atmospheric Science and Technology (CCAST), with the University of Arizona;
- Cooperative Institute for Atmospheric Research (CIFAR) Graduate Student Support, with UCLA;
- Center for the Study of Terrestrial and Extraterrestrial Atmospheres (CSTEA), with Howard University;
- Joint Interdisciplinary Earth Science Information Center (JIESIC) with George Mason University;
- Joint Center for Geoscience (JCG) at MIT;
- Cooperative Institute for Meteorological Satellite Studies (CIMSS) with the University of Wisconsin, Madison; and,
- Joint Center for Observation System Science (JCOSS) with the Scripps Institution of Oceanography, University of California, San Diego.

These joint centers have been organized to increase scientific interactions between the Earth Sciences Directorate at GSFC and the faculty and students at the participating universities. One means of increasing these interactions is a new initiative the Earth Sciences Directorate has established that will increase our sponsorship of graduate students. The Laboratory for Atmospheres is participating in this program, which will partner Laboratory scientists with graduate students. Our scientists will advise the student, serve on the thesis committee, visit the university, host the student at GSFC, and collaborate with the student's thesis advisor.

In addition, university and other outside scientists visit the Laboratory for periods ranging from 1 day to as long as 2 years. (See Appendix 1 for list of recent visitors and Appendix 4 for seminars.) Some of these appointments are supported by Resident Research Associateships offered by the National Research Council (NRC) of the National Academy of Sciences; others, by the Visiting Scientists and Visiting Fellows Programs currently managed by the Goddard Earth Sciences and Technology (GEST) Center. Visiting Scientists are appointed for up to 2 years and carry out research in pre-established areas. Visiting Fellows are appointed for up to 1 year and are free to carry out research projects of their own design. (See Appendix 3 for a list of NRC Research Associates, GEST Center Visiting Scientists, Visiting Fellows, and Associates of the Joint Institutes during 2001.)

Interactions with Other NASA Centers and Federal Laboratories

The Laboratory maintains strong, productive interactions with other NASA Centers and Federal laboratories.

Our ties with the other NASA Centers broaden our knowledge base. They allow us to complement each other's strengths, thus increasing our competitiveness while minimizing duplication of effort. They also increase our ability to reach the Agency's scientific objectives.

Our interactions with other Federal laboratories enhance the value of research funded by NASA. These interactions are particularly strong in ozone and radiation research, data assimilation studies, water vapor and aerosol measurements, ground truth activities for satellite missions, and operational satellites. An example of interagency interaction is the NASA/NOAA/NSF Joint Center for Satellite Data Assimilation (JCSDA), which is expanding prior collaborations between

NASA and NCEP to exploit the assimilation of satellite data for both operational and research purposes.

Interactions with Foreign Agencies

The Laboratory has cooperated in several ongoing programs with non-U.S. space agencies. These programs involve many of the Laboratory scientists.

Major efforts include the TRMM Mission, with the Japanese National Space Development Agency (NASDA); the Huygens Probe GCMS, with the ESA (CNES); the TOMS Program, with NASDA and the Russian Scientific Research Institute of Electromechanics (NIIEM); the Neutral Mass Spectrometer (NMS) instrument, with the Japanese Institute of Space and Aeronautical Science (ISAS); and climate research with various institutes in Europe, South America, Africa, and Asia.

Laboratory scientists interact with about 20 foreign agencies, about an equal number of foreign universities, and several foreign companies. The collaborations vary from extended visits for joint missions to brief visits for giving seminars or working on joint science papers. As a result of the joint U.S.-Japan Workshop on Relationships and Intercomparison of Monsoon Climate Systems, held in our Laboratory in 2000, participants have agreed to develop pilot research projects involving the U.S. Global Change Research Program and the Japanese Frontier Research System for Global Change to enhance studies of teleconnections or globally connected climate systems.

Commercialization and Technology Transfer

The Laboratory for Atmospheres fully supports Government/industry partnerships, SBIRs, and technology transfer activities. In recent years two members of the Laboratory received the annual James J. Kerley Award for outstanding contributions to technology commercialization. The Laboratory was extremely proactive, and a key contributor, to development of the partnering process now used within Goddard. Through this process Government PIs can team with industry to produce credible and competitive proposals that satisfy CICA (Competition In Contracting Act) requirements. The Laboratory used this process under the ESSP Program and will continue to use this process on all major mission proposals. Industry or university Co-Is are important contributors on each program. Laboratory scientists also serve as Co-Is on proposals led by industry. These practices will continue on future proposals.

During 2001 Code 912 researchers obtained a patent on a holographic circle-to-point converter optic (U.S. Patent #6313908). Recognizing the potential of the holographic optic, Scientific Solutions, Inc., a small Massachusetts-based company, licensed the technology from GSFC. Scientific Solutions is interested in using the holographic optic in several applications, including instruments for atmospheric remote sensing, instruments for medical imaging, and use in multiplexing/demultiplexing for telecommunications. Based on initial successes, Scientific Solutions has renewed its license for 2002.

Successful technology transfer has occurred on a number of programs in the past and new opportunities will become available in the future. Past examples include the micro pulse lidar and holographic optical scanner technology. Industry now develops and markets micro pulse lidar systems to an international community. A licensing agreement with industry permits the continued use of government-patented holographic technology for commercial applications to topographic mapping. New research proposals involving technology development will have strong commercial partnerships wherever possible. The Laboratory hopes to devote at least 10% to 20% of its resources to joint activities with industry on a continuing basis.